

**TITLE:** Downhole elemental analysis with LIBS

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**ABSTRACT BODY:** In this paper we discuss a novel instrument, currently under development at Honeybee Robotics with SBIR funding from NASA. The device is designed to characterize elemental composition as a function of depth in non-terrestrial geological formations. The instrument consists of a miniaturized LIBS analyzer integrated in a 2" diameter drill string. While the drill provides subsurface access, the LIBS analyzer provides information on the elemental composition of the borehole wall. This instrument has a variety of space applications ranging from exploration of the Moon for which it was originally designed, to Mars, as well as a variety of terrestrial applications.

Subsurface analysis is usually performed by sample acquisition through a drill or excavator, followed by sample preparation and subsequent sample presentation to an instrument or suite of instruments. An alternative approach consisting in bringing a miniaturized version of the instrument to the sample has many advantages over the traditional methodology, as it allows faster response, reduced probability of cross-contamination and a simplification in the sampling mechanisms.

LIBS functions by focusing a high energy laser on a material inducing a plasma consisting of a small fraction of the material under analysis. Optical emission from the plasma, analyzed by a spectrometer, can be used to determine elemental composition.

A triangulation sensor located in the sensor head determines the distance of the sensor from the borehole wall. An actuator modifies the position of the sensor accordingly, in order to compensate for changes due to the profile of the borehole walls. This is necessary because LIBS measurements are negatively affected by changes in the relative position of the focus of the laser with respect to the position of the sample (commonly referred to as the "lens to sample distance"). Profiling the borehole is done by adjusting the position of the sensor with a vertical stage; a second actuator at the top of the downhole probe allows radial scanning of the borehole.

Analysis of iron and titanium in lunar simulant with LIBS was performed in air using the method of standard addition. The results for lunar simulant NU-LHT-2M show a value for the concentration of iron ranging between 2.29% and 3.05% depending on the atomic line selected. The accepted value for the sample analyzed is 2.83%, showing the capability for the system in development to provide qualitative and semi-quantitative analysis in real-time.